

## MEMORANDUM

**Date:** May 15, 2008  
**To:** Sara Agahi  
**Organization:** San Diego County  
**From:** Andy Collison  
**PWA Project #:** 1915  
**PWA Project Name:** San Diego HMP  
**Subject:** Geomorphic analysis for interim Hydrograph Modification Plan (HMP)  
**Copy(ies) To:** File, Nancy Gardner

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### **Purpose of this memo**

The Interim HMP standard (February 2008) describes different options for applicants to prevent channel erosion as a result of increased runoff from developed sites. In addition to interim flow control standards and the option to use Low Impact Development (LID), there is a provision for applicants to carry out their own geomorphic assessment to demonstrate that the project will not cause erosion in the receiving water. This memo describes why an applicant might perform a geomorphic assessment and what such an assessment would typically involve.

### **Definitions of terms**

*Q5* – flow that recurs on average once every five years in the receiving water at the point of compliance.

*0.2Q5* – 20% of the 5-year flow.

*Q10* – flow that recurs on average once every ten years.

*Bankfull flood* – discharge that fully occupies the main scoured section of the creek channel (to top of bank for a non incised channel). In San Diego the bankfull flood is approximately the 5-year flow (*Q5*) under pre-development conditions.

*Beneficial uses* – uses designated by the RWQCB as beneficial for a given water body. Uses may include habitat, recreation, water supply etc.

*Boundary shear stress* – the erosive energy imparted by flowing water on the channel bed and banks.

*Critical shear stress* – the erosive energy above which flowing water causes sediment to start to erode from a creek bed or banks. Varies with particle size and cohesion.

*Channel-forming flow(s)* – the flow or range of flows that cumulatively transport the majority of sediment in a channel over a long period of time, and so control the size (cross sectional area) of the channel through erosion and deposition (also referred to as geomorphically-significant flows, or effective flows).

*Downstream limit of influence* – the point below which no significant effects of a development can be detected in the receiving channel. This can be due to one of three conditions (or a combination of all

three): channel becomes hardened all the way from this point to the ocean; channel becomes depositional from this point to the ocean, channel is joined by tributaries or is a tributary to another channel, where the cumulative flow of the combined channel is great enough that the project does not significantly alter the pre-project condition.

*Flow control* – measures involving enhanced infiltration or surface water detention that prevent runoff from leaving a developed site at an excessively high rate. For example, the interim flow control standard for the San Diego County HMP states that flows between 0.2Q5 and Q10 must be kept within 10% of pre-development flows over 10% of the flow duration curve.

*Receiving channel* – the pre-existing creek channel into which the project runoff is discharged

## **Background**

The ultimate objective of the HMP is to prevent erosion in stream channels that receive runoff from developments. Erosion occurs because following development small to medium size flows become larger and more frequent, and receiving channels enlarge their cross sections through bed and bank erosion to accommodate the higher flows. In addition, sediment reduction from landscaping and detention basins creates ‘hungry water’ which has a greater sediment capacity than the same volume of sediment-laden water. Channel erosion has impacts on the beneficial uses of the water body both at the receiving site, and downstream where excess sediment is ultimately deposited. HMPs seek to prevent erosion primarily by making the pre- and post-development runoff characteristics (flow duration and peak) match within the range of flows that are responsible for most erosion (sometimes referred to as the channel-forming, or effective, flows). Numerous studies have shown that this flow range lies approximately between a value less than the bankfull flood and a value around the 10-year flood. For the Interim HMP they have been set to 0.2Q5 and Q10, and these values are being examined for the final HMP. Flows below this range generally erode and transport little or no sediment, while flows above this range are so infrequent as to have little cumulative effect.

Whilst flow control (either through the use of LID or detention facilities) is seen as the primary means of preventing erosion, and the application of simple flow control standards or LID sizing factors is seen as the most efficient way of achieving control, the Interim HMP provides some exemptions, and also allows an applicant to perform their own geomorphic analyses. The relevant section in the Interim Standard states that an exemption may be granted if “the applicant conducts an assessment incorporating sediment transport modeling across the range of geomorphically-significant flows that demonstrates to the permitting agencies satisfaction that the project flows and sediment reductions will not detrimentally affect the receiving water.” There are also exemptions for hardened channels and depositional channels.

The purpose of a geomorphic assessment would be to demonstrate that a proposed project could discharge into a receiving channel in a manner that did not meet the flow control standard, but that would not cause erosion in the receiving water that exceeded pre-existing levels (within an agreed upon tolerance). This scenario may be possible for several reasons:

1. The flow control and LID standards in the HMP are average-to-conservative values, designed to simplify the application process for small projects and reduce the burden of analysis while still protecting creeks. Because rainfall, soils, topography and the nature of the receiving waters vary across the County there will be situations where less conservative flow controls or LID sizing factors will achieve creek protection.
2. The receiving channel may be depositional, so that increased flows from a project would simply bring the channel closer to sediment equilibrium.
3. In a large scale development it may be possible to configure the site's stormwater management system so that channel impacts are avoided with the use of slightly different flow controls than those put forwards in the Interim HMP (e.g. by de-synchronizing peak flows from different sub-watersheds).
4. The project may discharge into a flood channel that is so oversized that the flows would not be effective in causing erosion.

Because the potential sites and circumstances are variable, and the scale of the proposed developments varies, there is no standard prescriptive method of conducting such a geomorphic assessment. However, in this memo we lay out the required end products to demonstrate compliance and an example assessment of each of the most likely scenarios.

### **Geomorphic assessment examples**

#### *Conditions for all geomorphic assessments*

Whatever the circumstance, the geomorphic assessment must demonstrate that increased erosion will not occur after a site is developed. It must address the range of flows that is believed to be responsible for erosion (identified in the interim HMP as 0.2Q5 to Q10).

#### *Full runoff and sediment transport modeling of proposed site*

An applicant could develop a full sediment transport model of the receiving water from the discharge point to the downstream limit and conduct continuous simulation modeling to demonstrate that the project would not cause impacts to the stream, or that the proposed flow control standards are unnecessarily conservative for their development for site specific reasons. This would involve the following steps:

Step 1. Develop pre- and post-project rainfall runoff models and conduct continuous simulation modeling. (See companion memo Brown & Caldwell, 2008, on continuous rainfall-runoff modeling.) The modeling could take place using models including HEC-HMS, HSPF (or the HSPF-derived San Diego County Hydrology Model), or SWMM. A period of at least 30 years should be simulated using local rainfall records. The model timesteps should be sufficient to capture the peak flow from small events (annual or more frequent). For small watersheds (less than 5 square miles) this is likely to require hourly timesteps during rainfalls greater than one quarter inch total.

Step 2. Run pre- and post-development flows through a sediment transport model.

The flow records from Step 1 should be routed through a hydraulic-sediment transport model of the receiving channel to the downstream limit. Applicable models include HEC-RAS version 4 and higher, HEC-6, FLUVIAL 12, and MIKE-11. The resulting channel erosion from the pre- and post-development conditions should be compared.

*Applicant believes the channel is more resistant than average, and that some flows within the control range will not cause erosion.*

The lower flow threshold value (0.2Q5) is actually a surrogate for *critical shear stress*, which can be hard to measure in the field and varies from site to site. If the actual critical shear stress in the receiving channel is higher than the level assumed by the flow standard there would not be a rationale for controlling flows below this level. This could occur because the channel was formed in stiff clay, or had coarse gravel or cobble bed and banks. Therefore, an applicant could legitimately try to establish whether the critical shear stress of the receiving channel was higher than the boundary shear stress at 0.2Q5, and if successful raise the level for their project to the flow at this stress level. This condition would have to be met for the channel from the discharge point all the way to the downstream limit of influence.

#### *Potential assessment method*

Step 1. Identify the critical shear stress for the receiving water.

For sandy or coarser sediments this can be calculated from the median particle size and the Shields number:

$$\tau_c = \tau_c^* (\gamma_s - \gamma) d_{50}$$

where

$\tau_c$  = critical shear stress (Newtons per meter squared)

$\tau_c^*$  = dimensionless critical shear stress (Shields parameter – assumed to be 0.03)

$\gamma_s$  = specific weight of sediment (2.65 times water)

$\gamma$  = specific weight of water (9,807 N/m<sup>3</sup>)

$d_{50}$  = median particle size (meters)

(Critical shear stress is converted to pounds by multiplying by 0.02088)

For cohesive stream banks or beds there is no simple empirical relationship that can be used, and direct measurements are required. Critical shear stress for cohesive beds and banks can be measured in the field using a jet test (see Hansen and Cook, 2004). Alternatively undisturbed cores can be removed and testing in laboratory flumes. There are values in the literature associated with soil types, so potentially the soil

types in the channel could be mapped and use made of these literature values. Whichever method was used a statistically-significant number of tests would have to be performed to characterize the channel between the discharge point and the downstream boundary (e.g. points at 20-30 locations between the discharge point and the downstream boundary).

*Step 2. Identify flow associated with critical shear stress*

The discharge above which erosion occurs would be identified using hydraulic modeling of the receiving water. In medium to large developments this could be achieved most efficiently by developing a hydraulic model (e.g. HEC-RAS) of the creek and for each sampled location of critical shear stress identifying the corresponding flow that generates that boundary stress. Alternatively, for a small development, it would be appropriate to develop a spreadsheet model (Excel) of flow to calculate the average boundary shear stress at a series of flows and develop a rating curve.

*Step 3. Identify recurrence interval associated with the critical flow*

Recurrence interval for that flow could be calculated using the methods outlined in the San Diego County Flood Manual. If the flow associated with the critical shear stress is greater than 0.2Q5 the permittees could raise the flow control standard to the actual value for critical shear stress, reducing the amount of infiltration or detention capacity needed on site to meet the HMP criteria.

*Channel may be depositional*

If the channel is depositional from the discharge point to the downstream limit of influence then a slight increase in flow erosivity could have beneficial effects (move sediment to the ocean rather than have deposition in a channel). This condition is likely to occur on low gradient sites (flatter than 0.5% channel gradient) relatively close to the ocean.

The assessment could either develop a sediment transport model to show that the reach was depositional, or could use direct evidence. This could include using records to show that sediment was accumulating in the channel (county sediment removal records, photographic evidence, repeat channel cross sections, CALTRANS bridge resurveys etc). Due to the episodic nature of erosion and deposition in Southern California channels it is important that long term evidence be provided. For large increases in runoff and/or where the channel is only slightly aggradational the applicant must show that the project will not tip the channel into an erosive condition, using sediment transport modeling.

*Channel may be oversized*

If the project discharges into an oversized flood control channel erosion may not occur because the channel spreads flow over a large surface area, reducing boundary shear stresses. The applicant could demonstrate this by calculating the flows associated with the flow control range (0.2Q5 to Q10) and using a simple hydraulic model (Excel or 1D hydraulic model) to calculate the boundary shear stress in the

receiving channel. If some or all of the flow range is less than critical shear stress the applicant could seek a rise in the lower threshold to critical shear stress.

### **References**

Hanson, G. J., Cook, K. R. Apparatus, test procedures, and analytical methods to measure soil erodibility *in situ*. Applied Engineering in Agriculture, 2004 (Vol. 20) (No. 4) 455-462